America's Cement Manufacturers™

Portland Cement Association
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Lesson 5: So, You Think Concrete Dries Out?

Age: Grades 7-12
Subjects: Science
Skills: Description, proportioning, observation, small group work
Duration: 2 class sessions
Setting: Laboratory or classroom
Key Vocabulary: Hydration, mass, evaporation, tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetracalcium aluminoferrite, gypsum

Objective
Students will learn 1) The chemistry of cement 2) That concrete hydrates and the difference between hydration and drying 3) Principle of conservation of mass

Method
Students will learn about the hydration process by creating samples of concrete and weighing them before and after hydration. They will see that the samples lose no weight to evaporation because of the chemical reaction between cement and water.

Background
Concrete is made by the combination of cement, water, and aggregate of various sizes to make a workable slurry that has the consistency of a thick milk shake.

(See table on page 2)

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Name	Percent by Weight	Chemical Formula
Tricalcium silicate	50%	$3Ca0\ SO_2$
Dicalcium silicate	25%	$2Ca0\ SiO_2$
Tricalcium aluminate	10%	$3Ca0\ Al_2\ O_3$
Tetracalcium aluminoferrite	10%	$4Ca0\ Al_2\ Fe_2\ O_3$
Gypsum	5%	$CaSO_4\ H_2O$

The binding quality of portland cement paste is due to the chemical reaction between the cement and water, called hydration. Portland cement is not a simple chemical compound, it is a mixture of many compounds. Four of these make up 90% or more of the weight of portland cement: tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite. In addition to these major compounds, several other play important roles in the hydration process. Different types of cement contain the same four major compounds, but in different proportions.

The cement in concrete needs water to hydrate and harden. Even though the chemical reactions may be complete at the surface of the concrete, the chemical reactions at the interior of the concrete take much longer to complete. The strength of the concrete keeps growing as long as the chemical reactions continue.

When water is added to cement, the chemical reaction called hydration takes place and contributes to the final concrete product. The calcium silicates contribute most to the strength of concrete. Tricalcium silicates are responsible for most of the early strength (first seven days).

The original dicalcium silicate hydrates, which form more slowly, contribute to the strength of concrete at later stages. The following word equations describe the production of concrete.

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Tricalcium silicate + Water
(yields)

Calcium silicate hydrate + Calcium hydroxide + heat

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Of the five chemical reactions important for providing the strength for concrete the above reactions are the most important.

The two calcium silicates, which constitute about 75% of the weight of portland cement, react with water to form two new compounds: calcium hydroxide and calcium silicate hydrate. The latter is by far the most important cementing component in concrete. The engineering properties of concrete—setting and hardening, strength and dimensional stability—depend primarily on calcium silicate hydrate gel. It is the heart of concrete.

When concrete sets, its gross volume remains almost unchanged, but hardened concrete contains pores filled with water and air that have no strength. The strength is in the solid part of the paste, mostly in the calcium silicate hydrate and crystalline phases.

The less porous the cement paste, the stronger the concrete. When mixing concrete, therefore, use no more water than is absolutely necessary to make the concrete plastic and workable. Even then, the water used is far more than is required for complete hydration of the cement. The water-cement ratio (by weight) of completely hydrated cement is about 0.22 to 0.25, excluding evaporable water.

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Materials

Use a 40 lb bag of mortar mix, polystyrene cups, and a scale. Mortar is a concrete mix that uses sand as the only aggregate in the mixture.

Procedure

A common expression is, "Don't walk on the concrete until it dries!" One of the easiest ways to show that the hardening (curing) of concrete is not due to drying (the water becomes a part of the chemistry of concrete) is to use the principle of the conservation of mass.

Using polystyrene cups, weigh out 500 grams of mortar mix (sand and cement mixture), add 75 grams of water. Mix until the lumps disappear from the mortar mix. Weigh again to find the total weight and the added amount of water as a check. Set the cup with the concrete mixture aside as well as another polystyrene cup of water filled to about the same level as the cup with the concrete. Weigh the cup of water. Set the cup of water next to the cup of concrete. This cup of water is used to indicate how much water evaporates from the surface of the concrete before complete hardening occurs.

Wait about 24 hours and weigh each cup again. The concrete will have lost only a fraction of the water to evaporation from the exposed surface. You can compare the loss of water from the concrete with that of the cup of plain water that also lost some water due to evaporation. Both of these amounts of water are small when compared to the original amount of water added to the concrete that does not evaporate to make the hardened concrete. By comparing the amounts of original ingredients to the weight of the final concrete it is clear that the concrete does not dry out.

The concrete mixture may lose a little more water than the cup with the water only. If you look carefully you'll see that the concrete's surface is not smooth. This rougher surface area makes it possible for water to evaporate faster than the water in the cup alone. Again, this amount of water is negligible when compared to the water added into the concrete mixture that went into the chemical reaction to make the hardened

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material.

Discuss with students what efforts workers in the construction industry might take to eliminate evaporation from the surface of newly poured concrete.

Given this information, the expression given by the teacher at the beginning of this investigation needs to be more accurately stated. Ask the students to write a more accurate directive.